Semi-Annual Report

NASA Grant No. NGR39-009-032

"Study and Evaluation of the Constant-Momentum Mass Spectrometer for Ion Analysis in the D and E Regions of the Ionosphere"

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## 1. Summary

The work carried out under Grant No. NGR39-009-032 during the period 1 June to 1 December, 1965 can be summarized as follows:

A. The Laboratory's seventy-five liter vacuum chamber was completed and fitted with a gas-handling system and inlet valves for operation at controlled pressures.

B. A potassium ion source was developed to give steady controllable fluxes of potassium ions.

C. A new method was developed for assembling ion optical devices to be exposed to large mechanical stresses.

D. An experimental constant-momentum mass spectrometer was constructed and initial tests were carried out.

## 2. Vacuum Chamber

A schematic diagram of the chamber is shown in Figure 1. It is basically a conventional system to which has been added an experimental zeolite-lined fore-line trap, a time-of-flight partial pressure monitor, and gas inlet lines and expansion volumes to allow controlled admission of pure gases. The time-of-flight partial pressure monitor is a miniaturized version of one described previously in the literature.[1] The pump-down time from atmospheric pressure to $10^{-5}$ torr is less than four minutes, with an ultimate pressure in the $10^{-8}$ torr range.

The system is at present in continuous operation for tests on experimental constant-momentum mass spectrometers.

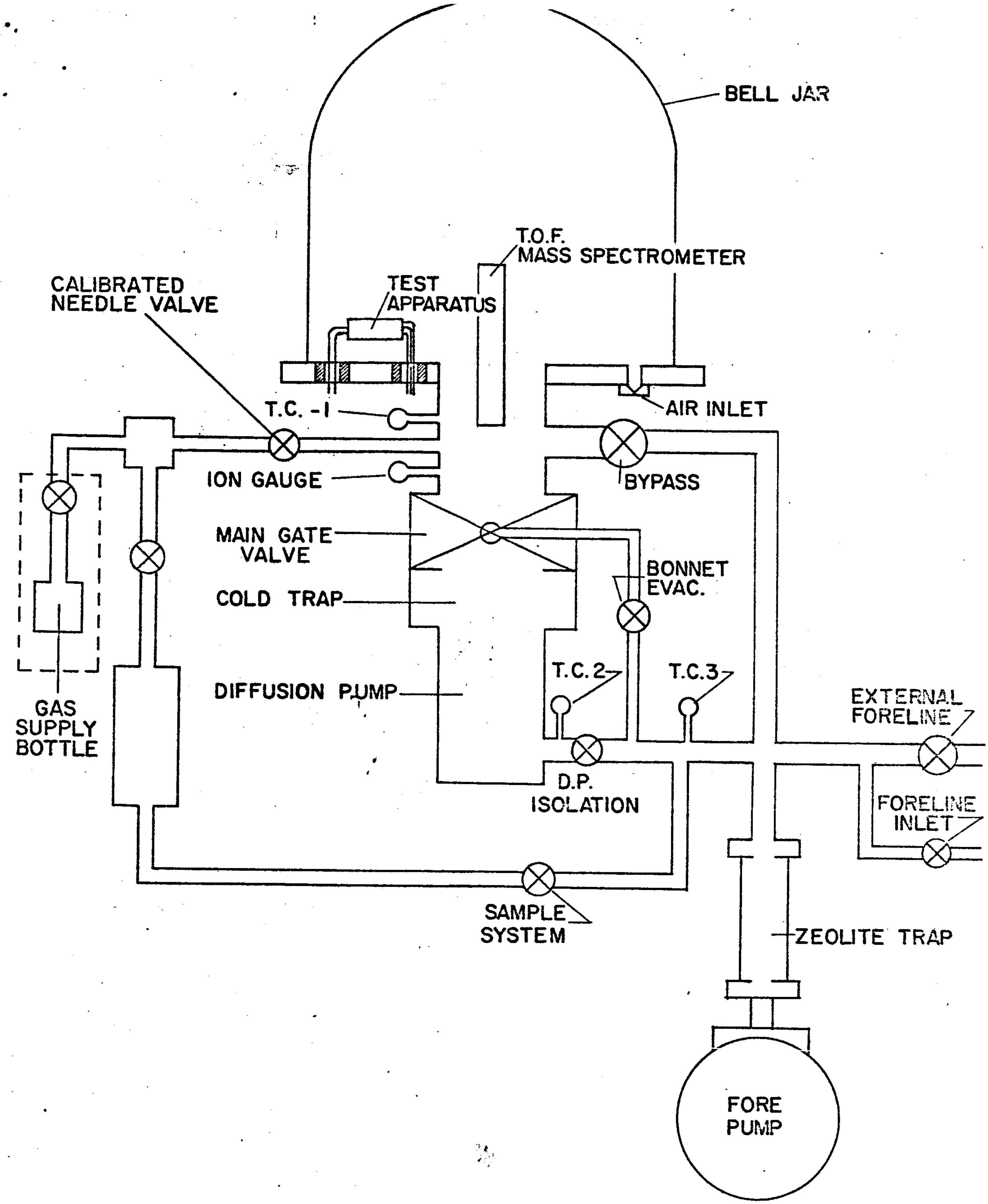


FIG. I VACUUM CHAMBER AND PUMPING SYSTEM

3. Potassium Ion Source

A surface ionization source loaded with a potassium alumino-silicate is used. It differs from conventional sources of this type in having improved shielding to prevent emission from points off the electrical center of the filament. A grid in front of the emitter accelerates ions away from the emitting surface. They are then decelerated before drifting at low velocities into the pulsed-field region of the actual mass spectrometer.

4. A New Method for Assembling Ion-Optical Devices

An epoxy adhesive had been used successfully in bonding zeolite pellets to metal surfaces in the fore-line trap mentioned previously. When the need arose for insulating metal-to-metal bonds in the energy analyzer of the constant momentum mass spectrometer, tests were carried out with other types of adhesives containing solid mica and glass additives. These investigations finally led to a new method for assembling experimental ion-optical apparatus, electron devices and other similar equipment.

With this method, no separate insulators are used. Instead, a mixture of heat resistant silicone or polyimide resins and small glass spheres is used to bond the metal electrodes directly to one another.

The glass spheres keep the adjacent metal surfaces parallel and a small distance apart, thus insuring adequate electrical insulation. Spheres ranging in diameter from 0.005 to 0.033 inches are used, depending on the voltage differences between the adjacent electrodes. The larger sizes can be used with inter-electrode voltages up to well above 1,000 volts.

Devices assembled with the silicone resin-glass sphere mixtures have good resistance to mechanical shock, will withstand temperatures up to 300$^{\circ}$C, and can be used satisfactorily in conjunction with ordinary diffusion-pumped vacuum systems. The good thermal conductivity of the bonding material is especially useful where heat must be transferred between components at different potentials.

Although the new method is not expected to replace conventional assembly techniques in most applications, it does appear to offer useful savings in complexity, size, weight and construction time when used for experimental devices being built in small numbers. The method is now being evaluated for possible use in constructing rocket-borne apparatus which must withstand large accelerations.

## 5. Experiments with the Constant-Momentum Mass Spectrometer

A drawing of the apparatus presently in use is shown in Figure 2. Ions from the source are given constant momentum in the pulsed-field region and attain energies given by

$$E = \frac{k\,V^2\,t^2}{md^2} ,$$

where E is in electron volts, m is the ionic mass in atomic mass units, d is the distance in centimeters between electrodes 1 and 2, V is in volts, t is in microseconds, and k is a constant with a

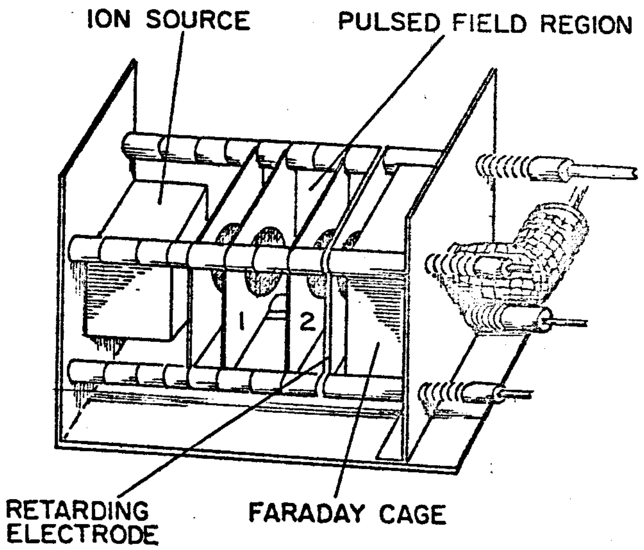


FIG. 2
CONSTANT MOMENTUM
MASS SPECTROMETER

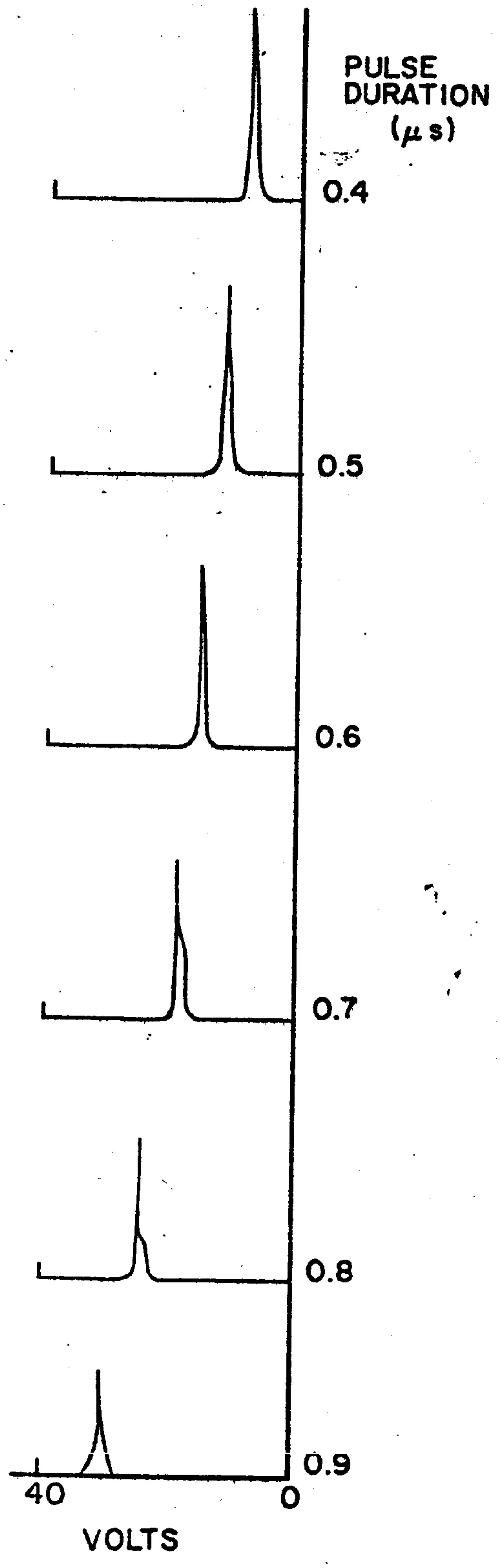


FIG. 3 EFFECT OF VARYING t

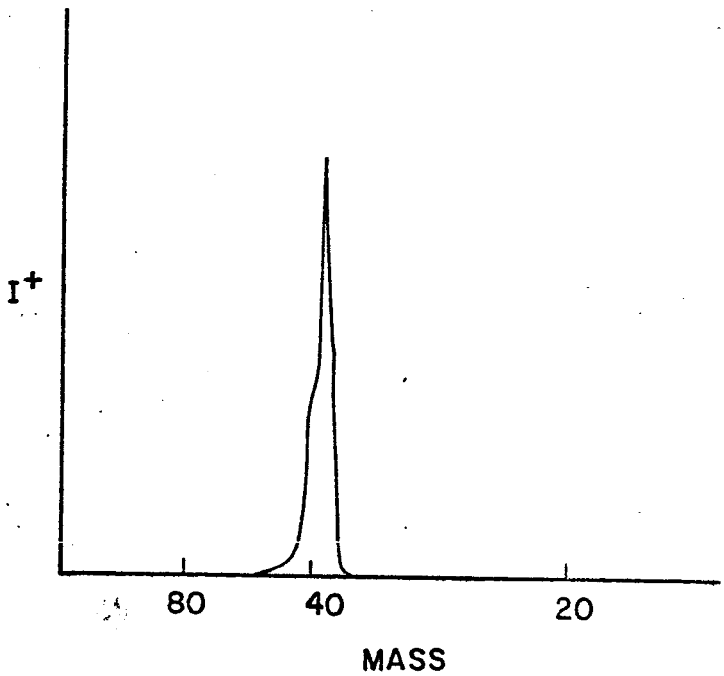


FIG. 4 MASS SPECTRUM FOR POTASSIUM
(MASSES 39 AND 41)

value of approximately 0.48.

The voltage applied to a retarding electrode is swept by a sweep generator to give an ion current versus retarding potential trace. This, when differentiated, gives the mass spectrum.

The most recent tests have been with a system in which grid 2 is pulsed negative by the main pulse and grid 1 is gated to admit ions only at the beginning of the main pulse.

A set of differential traces for potassium ions for different values of the constant t is shown in Figure 3. Figure 4 shows a typical mass spectrum.

The maximum operating pressure in the experiments so far carried out was just under $10^{-3}$ torr, which corresponds approximately to an altitude of 100 kilometers. At this simulated altitude the resolving power is degraded to only a very slight degree, supporting the original contention that this type of instrument has special advantages for high pressure operation.

## 6. Publications and Papers delivered at Conferences

A paper entitled "High Temperature Insulating Adhesives for Vacuum Applications" by B. R. Kendall and M. F. Zabielski was delivered at the 13th Annual American Vacuum Society Symposium in New York City, October, 1965. A more complete version under the same title has been submitted for publication in "American Journal of Vacuum Science and Technology".

Another paper entitled "Apparatus for Teaching and Research in Electron Optics" is in preparation.

## 7. Personnel

The work described in this report was carried out by: H. M. Luther, M. F. Zabielski, and B. R. Kendall, principal investigator.

## 8. Future Work

During the next six-month period the theory of the constant momentum mass spectrometer will be investigated in more detail, with emphasis on possible circularly symmetrical versions and on methods of correcting for initial energy variations in the incident ions.

Experimental tests will be continued using a gaseous ion source to give a wider variety of ions. A series of tests at higher pressures than have previously been used will also be undertaken.

A number of modifications to the high vacuum chamber will also be carried out. Some of these modifications are desirable in order to minimize possible damage to the system in the event of prolonged electrical power failures. Other and more minor changes are necessary in order to improve the reliability of some of the protective circuits and the automatic liquid nitrogen refilling system.

## 9. References

1. Kendall, B.R.F., Jour. Sci. Instr. 39, 267 (1962).